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Indian Standard

METHODS FOR THE ASSESSMENT OF DEPARTURE FROM ROUNDNESS — MEASUREMENT BY TWO- AND THREE-POINT METHODS

ICS 17.040.20

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are specified in IS 15373 : 2003/ISO 4291 : 1985 'Method for the assessment of departure from roundness — Measurement of variations in radius'.

In this adopted standard reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their place, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 4291 : 1985	IS 15373 : 2003 Methods for the assessment of departure from roundness — Measurement of variations in radius	Identical
ISO 6318 : 1985	IS 15372 : 2003 Measurement of roundness — Terms, definitions and parameters of roundness	do

The text of ISO Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear, referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker in the International Standard while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off; it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

METHODS FOR THE ASSESSMENT OF DEPARTURE FROM ROUNDNESS — MEASUREMENT BY TWO- AND THREE-POINT METHODS

1 Scope and field of application

This International Standard specifies methods of numerical assessment of out-of-roundness determined by the combination of two- and three-point measurement:

a) determination by means of two-point measurement (measurement of diameters);

b) determination by means of three-point measurement, summit (symmetrical or asymmetrical setting);

c) determination by means of three-point measurement, rider (symmetrical setting).

Any statement regarding an out-of-round section is incomplete unless the extent and nature of the departures from roundness are given. Methods for making such descriptions and evaluating them are specified in ISO 4291.

For routine or in-process inspection, the procedure specified in ISO 4291 may either be needlessly accurate or the items to be inspected may be too large to be accommodated.

The methods specified give faster and cheaper ways of assessing departures from roundness. This assessed value will deviate from the true value. The difference between the measured value and the true value can be estimated with the help of tables 2 to 8, assuming that the undulation numbers are known and of sinusoidal nature. For non-sinusoidal undulations, a theory for estimating such deviations is not yet available.

2 References

ISO 4291, *Methods for the assessment of departure from roundness — Measurement of variations in radius.*

ISO 6318, *Measurement of roundness — Terms, definitions and parameters of roundness.*

3 Definitions

For the purpose of this International Standard, the definitions given in ISO 6318 and the following apply.

3.1 two-point measurement: Measurement between coaxial anvils, one fixed and one moving in the direction of measurement.

See figures 1 and 2.

3.2 three-point measurement: Measurement between anvils, two fixed and one moving in the direction of measurement.

See figures 3 to 8.

3.2.1 summit method: A three-point measurement in which the two fixed anvils are situated on one side and the measuring anvil is situated on the other side of the workpiece axis in the plane of measurement.

See figures 3, 4, 6 and 7.

3.2.2 rider method: A three-point measurement in which the two fixed anvils are situated on the same side as the measuring anvil in the plane of measurement.

See figures 5 and 8.

3.3 symmetrical (three-point) setting: A setting at which the direction of measurement coincides with the bisector angle between fixed anvils.

See figures 3, 5, 6 and 8.

3.4 asymmetrical (three-point) setting: A setting at which the direction of measurement constitutes an angle with the bisector angle between fixed anvils.

See figures 4 and 7.

4 Measurement

In order to cover all possible form deviations and numbers of undulations, a complete measurement should always consist of one two-point measurement and two three-point measurements at different angles between fixed anvils. In this International Standard, several alternatives are given when choosing angles between fixed anvils (see table 1). The measurement procedures may, under certain preconditions, be amplified. See tables 2 to 4.

Table 1 — Angles between fixed anvils

Symmetrical setting	Asymmetrical setting	
Angle between fixed anvils, α	Angle between fixed anvils, α	Angle between direction of measurement and bisector of angle between fixed anvils, β
90° and 120°	120°	60°
72° and 108°	60°	30°

The corrected value of the departure from roundness, δ, is given by the equation

$$\delta = \frac{\Delta}{F}$$

where

Δ is the measured departure from roundness — it is the largest value obtained from the preceding two or three combinations of angles received in the required measurements;

F is the correction factor — it has a value extracted from tables 2 to 8 (as a first approximation, F may be given a value of 2).

When measuring workpieces with a known even or odd number of undulations, the three-point measurement with symmetrical setting at 60° angles between fixed anvils may be used according to table 8. This angle is useful as it gives measured values of higher correction factors than the other angles in this International Standard. When using the 60° angle, the measured value shall be corrected with the factor F given in table 8.

5 Evaluation of measurement errors

Tables 5 to 7 give true factors F for any given number of sinusoidal undulations and measuring method.

If the number of sinusoidal undulations is known, the calculation of the departure from roundness is made by using the F factors directly from tables 5, 6, or 7 as indicated in tables 2, 3, or 4.

It is not possible to calculate exactly the departure from roundness if the number of undulations is unknown. In these cases a maximum, average and minimum value of δ can be calculated from the equation in clause 4 using the largest Δ value and the factors obtained from tables 2, 3 or 4.

There is a limit on the maximum number of undulations to be used when selecting F, according to whether the number of undulations is known and whether this number is an odd or even value. This precondition is shown in tables 2 to 4.

For 90° and 120° settings, the limit is 22, which assumes that a greater number of undulations than this will not have any appreciable effect on the factor F.

For 72° and 108° settings, the limit is determined by the fact that for 19 undulations the factor F cannot be determined.

Factors F for three-point measurement, symmetrical setting, are given in table 8.

NOTE — When using tables 5 to 8, other combinations of setting, besides those given in tables 2 to 4, can be made.

6 Measuring conditions and instrument

6.1 Measuring anvil static force

The static measuring force should not exceed 1 N. The force should, preferably, be adjustable and set at the lowest value that will ensure continuous contact between anvil and the surface being measured.

For thin-walled workpieces, a high measuring force may affect the measuring result. Therefore it is necessary to reduce the force to the minimum value possible.

6.2 Measuring anvils

Depending on the form of the object, the measuring anvil shall be selected from table 9, unless otherwise specified.

6.3 Fixed anvils

Point or line contact shall always be used. The following are recommended:

- for external measurement: V-support with a small radius; the median plane of the V-support shall be in the same plane as the plane of measurement.
- for internal measurement: sphere with a small radius; the median plane of the sphere shall be in the same plane as the plane of measurement.

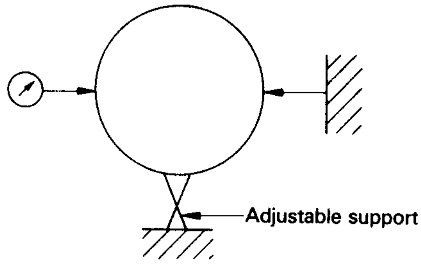

Figure 1 — Two-point measurement

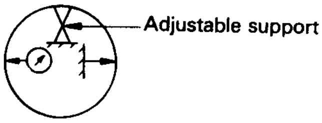

Figure 2 — Two-point measurement

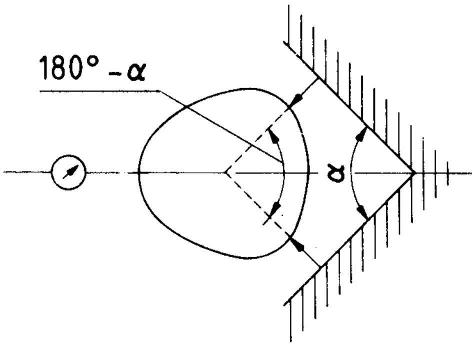

Figure 3 — Three-point measurement — Summit method — Symmetrical setting

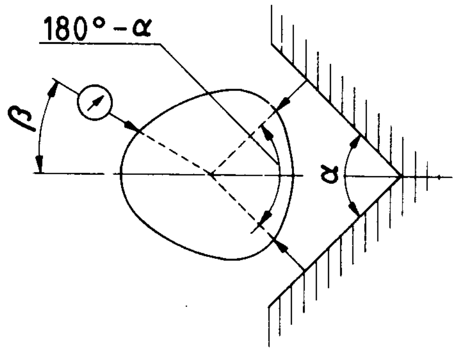

Figure 4 — Three-point measurement — Summit method — Asymmetrical setting

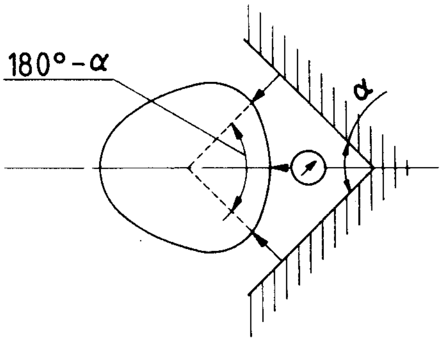

Figure 5 — Three-point measurement — Rider method — Symmetrical setting

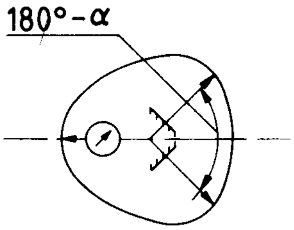

Figure 6 — Three-point measurement — Summit method — Symmetrical setting

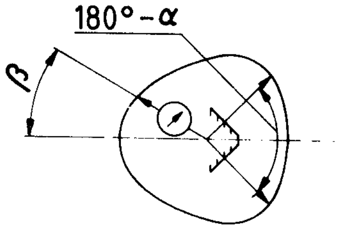

Figure 7 — Three-point measurement — Summit method — Asymmetrical setting

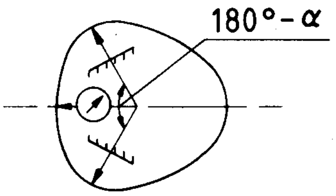

Figure 8 — Three-point measurement — Rider method — Symmetrical setting

Table 2 — 90° and 120°, symmetrical setting

Number of undulations, n_s \ Combination of settings	2 1) and 3S 90° 2) and 3S 120° 3)	2 1) and 3R 90° 4) and 3R 120° 5)	2 1)	3S 90° 2) and 3S 120° 3)	3R 90° 4) and 3R 120° 5)
	Factors *F*				
n_s unknown, but assumed to be $2 < n_s < 22$	max. 2,41 av. 1,95 min. 1,00	max. 2,41 av. 1,98 min. 1,00	—	—	—
n_s even but unknown, but assumed to be $2 < n_s < 22$	—	—	2,00	max. 2,41 av. 1,47 min. 0,42	max. 2,41 av. 1,70 min. 1,00
n_s odd but unknown, but assumed to be $3 < n_s < 21$	—	—	—	max. 2,00 av. 1,80 min. 1,00	max. 2,00 av. 1,80 min. 1,00
n_s even and known	—	—	2,00	exact 6)	exact 6)
n_s odd and known	—	—	—	exact 6)	exact 6)

1) Two-point measurement.

2) Three-point measurement, summit, $\alpha = 90°$.

3) Three-point measurement, summit, $\alpha = 120°$.

4) Three-point measurement, rider, $\alpha = 90°$.

5) Three-point measurement, rider, $\alpha = 120°$.

6) If multiplied by factors *F* according to table 5.

Table 3 — 72° and 108°, symmetrical setting

Number of undulations, n_s \ Combination of settings	2 1) and 3S 72° 2) and 3S 108° 3)	2 1) and 3R 72° 4) and 3R 108° 5)	2 1)	3S 72° 2) and 3S 108° 3)	3R 72° 4) and 3R 108° 5)
	Factors *F*				
n_s unknown, but assumed to be $2 < n_s < 18$	max. 2,62 av. 2,09 min. 1,38	max. 2,70 av. 2,11 min. 1,38	—	—	—
n_s even but unknown, but assumed to be $2 < n_s < 22$	—	—	2,00	max. 2,70 av. 1,00 min. 0,38	max. 2,70 av. 1,04 min. 0,62
n_s odd but unknown, but assumed to be $3 < n_s < 17$	—	—	—	max. 2,62 av. 2,06 min. 1,38	max. 2,62 av. 2,06 min. 1,38
n_s even and known	—	—	2,00	exact 6)	exact 6)
n_s odd and known	—	—	—	exact 6)	exact 6)

1) Two-point measurement.

2) Three-point measurement, summit, $\alpha = 72°$.

3) Three-point measurement, summit, $\alpha = 108°$.

4) Three-point measurement, rider, $\alpha = 72°$.

5) Three-point measurement, rider, $\alpha = 108°$.

6) If multiplied by factors *F* according to table 6.

Table 4 — 60°/30° and 120°/60°, asymmetrical setting

Combination of settings / Number of undulations, n_s	2 1) and 3S 60°/30° 2)	2 1) and 3S 60°/30° 2) and 3S 90° 3)	2 1) and 3S 120/60° 4)	2 1) and 3S 120°/60° 4) and 3S 90° 3)	2 1)	3S 60°/30° 2)	3S 120°/60° 4)
	Factors F						
n_s unknown, but assumed to be $2 < n_s < 10$	2	max. 2,41 av. 2,04 min. 2,00	max. 2,38 av. 2,08 min. 2,00	max. 2,41 av. 2,13 min. 2,00	—	max. 2,00 av. 1,60 min. 0,73	max. 2,38 av. 1,69 min. 0,42
n_s unknown, but assumed to be $2 < n_s < 22$	—	max. 2,73 av. 2,07 min. 2,00	—	max. 2,41 av. 2,11 min. 2,00	—	—	—
n_s even but unknown, but assumed to be $2 < n_s < 22$	—	—	—	—	2	max. 2,73 av. 1,41 min. 0,73	max. 2,38 av. 1,45 min. 0,42
n_s odd but unknown, but assumed to be $3 < n_s < 9$	2	2	2	2	—	2	2
n_s odd but unknown, but assumed to be $3 < n_s < 21$	—	2	—	2	—	—	—
n_s even and known	—	—	—	—	2	exact 5)	exact 5)
n_s odd and known	—	—	—	—	—	exact 5)	exact 5)

1) Two-point measurement.

2) Three-point measurement, summit, $\alpha = 60°$; $\beta = 30°$.

3) Three-point measurement, summit, $\alpha = 90°$ (symmetrical setting).

4) Three-point measurement, summit, $\alpha = 120°$; $\beta = 60°$.

5) If multiplied by factors F according to table 7.

Table 5 — Factors *F* for 90° and 120°, symmetrical setting

Number of undulations, n_s	Factors *F*				
	2 1)	3S 90° 2)	3S 120° 3)	3R 90° 4)	3R 120° 5)
2	2	1	1,58	1	0,42
3	– 6)	2	1	2	1
4	2	0,41	0,42	2,41	1,58
5	– 6)	2	2	2	2
6	2	1	0,16	1	2,16
7	– 6)	– 6)	2	– 6)	2
8	2	2,41	0,42	0,41	1,58
9	– 6)	– 6)	1	– 6)	1
10	2	1	1,58	1	0,42
11	– 6)	2	– 6)	2	– 6)
12	2	0,41	2,16	2,41	0,16
13	– 6)	2	– 6)	2	– 6)
14	2	1	1,58	1	0,42
15	– 6)	– 6)	1	– 6)	1
16	2	2,41	0,42	0,41	1,58
17	– 6)	– 6)	2	– 6)	2
18	2	1	0,16	1	2,16
19	– 6)	2	2	2	2
20	2	0,41	0,42	2,41	1,58
21	– 6)	2	1	2	1
22	2	1	1,58	1	0,42

1) Two-point measurement.

2) Three-point measurement, summit, $\alpha = 90°$.

3) Three-point measurement, summit, $\alpha = 120°$.

4) Three-point measurement, rider, $\alpha = 90°$.

5) Three-point measurement, rider, $\alpha = 120°$.

6) In this case the method gives no indication of deviation from roundness.

Table 6 — Factors *F* for 72° and 108°, symmetrical setting

Number of undulations, n_s	Factors *F*				
	2 1)	3S 72° 2)	3S 108° 3)	3R 72° 4)	3R 108° 5)
2	2	0,47	1,38	1,53	0,62
3	– 6)	2,62	1,38	2,62	1,38
4	2	0,38	– 6)	2,38	2
5	– 6)	1	2,24	1	2,24
6	2	2,38	– 6)	0,38	2
7	– 6)	0,62	1,38	0,62	1,38
8	2	1,53	1,38	0,47	0,62
9	– 6)	2	– 6)	2	– 6)
10	2	0,70	2,24	2,70	0,24
11	– 6)	2	– 6)	2	– 6)
12	2	1,53	1,38	0,47	0,62
13	– 6)	0,62	1,38	0,62	1,38
14	2	2,38	– 6)	0,38	2
15	– 6)	1	2,24	1	2,24
16	2	0,38	– 6)	2,38	2
17	– 6)	2,62	1,38	2,62	1,38
18	2	0,47	1,38	1,53	0,62
19	– 6)	– 6)	– 6)	– 6)	– 6)
20	2	2,70	2,24	0,70	0,24
21	– 6)	– 6)	– 6)	– 6)	– 6)
22	2	0,47	1,38	1,53	0,62

1) Two-point measurement.

2) Three-point measurement, summit, $\alpha = 72°$.

3) Three-point measurement, summit, $\alpha = 108°$.

4) Three-point measurement, rider, $\alpha = 72°$.

5) Three-point measurement, rider, $\alpha = 108°$.

6) In this case the method gives no indication of deviation from roundness.

Table 7 — Factors *F* for 120°/60° and 60°/30°, asymmetrical setting

Number of undulations, n_s	Factors *F*		
	2 1)	3S 120°/60° 2)	3S 60°/30° 3)
2	2	2,38	1,41
3	— 4)	2	2
4	2	1,01	1,41
5	— 4)	2	2
6	2	0,42	0,73
7	— 4)	2	2
8	2	1,01	1,41
9	— 4)	2	2
10	2	2,38	1,41
11	— 4)	— 4)	— 4)
12	2	1,58	2,73
13	— 4)	— 4)	— 4)
14	2	2,38	1,41
15	— 4)	2	2
16	2	1,01	1,41
17	— 4)	2	2
18	2	0,42	0,73
19	— 4)	2	2
20	2	1,01	1,41
21	— 4)	2	2
22	2	2,38	1,41

1) Two-point measurement.

2) Three-point measurement, summit, $\alpha = 120°$; $\beta = 60°$.

3) Three-point measurement, summit, $\alpha = 60°$; $\beta = 30°$.

4) In this case the method gives no indication of deviation from roundness.

Table 8 — Factors *F* for 60°, symmetrical setting

Number of undulations, n_s	Factors *F*	
	3S 60° 1)	3R 60° 2)
2	— 3)	2
3	3	3
4	— 3)	2
5	— 3)	— 3)
6	3	1
7	— 3)	— 3)
8	— 3)	2
9	3	3
10	— 3)	2
11	— 3)	— 3)
12	3	1
13	— 3)	— 3)
14	— 3)	2
15	3	3
16	— 3)	2
17	— 3)	— 3)
18	3	1
19	— 3)	— 3)
20	— 3)	2
21	3	3
22	— 3)	2

1) Three-point measurement, summit, $\alpha = 60°$.

2) Three-point measurement, rider, $\alpha = 60°$.

3) In this case the method gives no indication of deviation from roundness.

Table 9 — Measuring anvils

Dimensions in millimetres

Surface form	Anvil radius	Surface radius
Convex surface (spherical)	2,5	All
Convex edge (cylindrical)	2,5	All
Concave surface (spherical)	2,5	> 10
Concave edge (cylindrical)	2,5	> 10
Concave surface (spherical)	0,5	< 10
Concave edge (cylindrical)	0,5	< 10

NOTE — In the case of the external measurement using the two-point method, the flat type anvil (radius = ∞) shall be used.

Annex

Roundness measurement by two- and three-point methods — Worked examples of the use of factors F

A.1 Example 1

A centreless ground workpiece is to be checked. It is known that a three-lobed shape is present.

Available measuring equipment measures two-point; three-point, summit, $\alpha = 72°$; and three-point, summit, $\alpha = 108°$.

Measured results obtained

	2	3S 72°	3S 108°
Δ	1 µm	8 µm	3 µm

A.1.1 Calculation of the departure from roundness

For three sinusoidal undulations, table 6 shows:

	2	3S 72°	3S 108°
F	not applicable	2,62	1,38
$\delta\ (= \Delta/F)$	not applicable	$\frac{8}{2{,}62} \approx 3$ µm	$\frac{3}{1{,}38} \approx 2$ µm

Take as the departure from roundness the maximum value of δ, i.e.

$$\delta_{\max} \approx 3 \text{ µm}$$

A.1.2 Approximation of the departure from roundness

$$F = 2$$

$$\delta = \frac{\Delta_{\max}}{2} = \frac{8}{2} = 4 \text{ µm}$$

A.2 Example 2

A turned cylindrical bore is to be checked.

Available measuring equipment measures two-point; three-point, summit, $\alpha = 90°$; and three-point, summit, $\alpha = 120°$.

	2	3S 90°	3S 120°
Δ	2 µm	30 µm	27 µm

A.2.1 Calculation of the departure from roundness

By comparing the results obtained with the given factors F (two-point near zero, 90° and 120° values almost equal), table 5 indicates that there are 5 or 19 sinusoidal undulations.

For 5 and 19 lobes, the following factors F are given:

	2	3S 90°	3S 120°
F	not applicable	2	2
$\delta\ (= \Delta/F)$	not applicable	$\frac{30}{2} = 15$ µm	$\frac{27}{2} = 14$ µm

Take as the departure from roundness the maximum value of δ, i.e.

$$\delta_{\max} = 15 \text{ µm}$$

A.2.2 Approximation of the departure from roundness

$$F = 2$$

$$\delta = \frac{\Delta_{\max}}{2} = \frac{30}{2} = 15 \text{ µm}$$

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